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Is there seasonal variation in size and mass of Red Admirals Vanessa atalanta on Capri, Italy?

Finns det någon säsongsberoende variation i storlek och vikt hos amiraler Vanessa atalanta på Capri, Italien?

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Abstract

I present data on seasonal variation in wing length and mass of Red Admirals Vanessa atalanta captured on Capri, Italy, during spring and autumn. The Red Admiral is a migratory butterfly that migrates north throughout Europe each year and then heads back south in the autumn. During the winter they are mostly found in the northern Mediterranean area where they previously were thought to hibernate, but recent data suggest that a new generation is produced before spring migration. The Red Admirals captured on Capri showed no difference in dry mass between the two seasons, when taking size in account, but had significantly longer wings in autumn. This suggests that a new generation is produced during winter.

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Introduction

The Red Admiral *Vanessa atalanta* is one of the most regular long distance migrants among the European butterflies (Pollard & Yates 1993). It shows a clear bi-directional migration, heading north from the Mediterranean area in spring (Benvenuti et al. 1996) before reproducing (Henriksen & Kreutzer 1982). In late summer it returns south, as reported from field studies made at different locations in northern Europe (Williams 1951, Hansen 2001, Mikkola 2003). The numbers found in the northern parts of Europe are fluctuating, with smaller populations in cold summers, but the Red Admiral is much more regular there than most other migrating butterflies, for example the closely related Painted Lady *Vanessa cardui*. In England, where small numbers of Red Admirals regularly hibernate, the numbers found in early spring before the first true migrants arrive are not correlated with numbers found in the following autumn, suggesting that the population is completely dependent on immigration in the northern parts of Europe (Pollard & Greatorex-Davies 1998). It was initially believed that European Red Admirals migrated short distances and hibernated during winter, and that the same individuals returned north again in spring to produce the next generation (Roer 1961). This was later questioned, as Red Admirals were found to be poorly adapted to hibernation (Lempke 1971). Recently, Stefanescu (2001) found that in north-eastern Spain, reproduction occurred during the winter, and he suggested that the Mediteranean area as a whole is a breeding area rather than a wintering area for the adults of migrant populations of the Red Admiral.

Most studies on butterfly migration have been made on American Monarchs *Danaus plexippus*, that migrate across North America each year (Brower 1996). The majority of the monarch population spends the winter in Mexico, hibernating without additional feeding. To survive the winter, they need to build up large lipid stores before they reach the hibernation areas and the difference in lipid content can therefore vary dramatically during the year. Some individuals have lipid stores as large as 134% of their lean mass, compared to newly hatched individuals which have a lipid store of about 30%, which still is more than butterflies in general (Beall 1948). Not much is known about lipid accumulation in other species of migrating butterflies. The monarch studies show that large variations are likely to occur based on the current need of the butterfly. From these studies we also know that mass is often closely correlated with lipid content if size is controlled for (Brown

& Chippendale 1974). Also in studies where size was not controlled for, lean mass was fairly constant, compared to lipid content which showed much larger differences (Beall 1948). Therefore, mass looks promising as a quick and easy way for measurements of lipid stores in butterflies.

In this paper, I will present some data on size and dry mass differences in Red Admirals caught during spring and autumn on Capri, Italy. Since Capri is located well inside the winter range of the species, seasonal differences between individuals found here might tell us more about the winter ecology in this species.

Materials and methods

Red Admirals were captured on Capri 1–10 October 2004 and 9–20 May 2005. The butterflies were primarily caught to be used in orientation experiments; therefore measurements of hindwing length and dry mass were taken after these experiments, to avoid adverse effects on the orientation results from the handling. Prior to the orientation experiments, usually three days, all the butterflies had constant access to fructose solution which they fed on during the time in captivity. Immediately after the experiments the butterflies were killed with ethyl acetate. The length of the hindwing was recorded to the nearest 0.5mm with a digital calliper (DCA-150, Velleman components) and the head was removed for use in DNA studies. Only individuals with unabraded hindwings were included in the analysis. The thorax and abdomen were placed in plastic test tubes with rubber sealed caps and put in a freezer. The abdomen of all the collected butterflies was dissected to determine sex by inspection of their genitalia. After dissection the butterflies were dried in 70°C for 24 hours and the dry mass of thorax and abdomen was measured separately on a balance (Mettler Toledo AG 245). Since butterflies feed on liquid food which contain high amounts of water their mass can increase much after feeding (Christer Wiklund & Fredrik Stjernholm, personal communication), therefore dry mass is a more reliable estimate of lipid content than wet mass.

Statistics

To get a linear fit between the length of the hindwing and dry mass the wing measurements were raised to the power of three. To analyse differences in dry masses of thorax and abdomen between seasons, Analysis of Covariance (ANCOVA) with length of hindwing3 as covariate was used. To investigate differences in the Red Admirals' length of hindwing between the two seasons I used Mann-Whitney U-Test, since the residuals were not normally distributed. All statistical calculations were performed with Statistical Program for Social Sciences (SPSS) 11.0 for Windows.

Results

A total of 42 Red Admirals were captured, 21 in spring and 21 in autumn. All of the individuals were males. There was a significant correlation between the cube of hindwing length and dry mass of abdomen, and no significant effect of season (Table 1a). The same relationship was found for thorax dry mass (Table 1b) but the variation (Fig 1b) was smaller than for abdomen dry mass (Fig 1a). From the plotted data (Fig 1a & b) it was clear that the autumn individuals have longer hindwings. This difference in mean hindwing length was highly significant (Mann-Whitney U test, $U = 65.5$, $N_1 = 21$, $N_2 = 21$, $p < 0.0001$). The mean hindwing length and standard deviation was 23.79 ± 1.04 mm for the spring individuals compared to 25.71 ± 1.31 mm for the autumn individuals.

Table 1. Results of the ANCOVA test on dry mass of abdomen and thorax from male Red Admirals caught during spring and autumn on Capri, Italy. The interaction between hindwing length and season was nonsignificant ($p>0.05$) in both cases and thus removed from the final calculations.
Resultat av ANCOVA-test avseende torrvikt för abdomen och thorax hos hanar av amiraler fångade under vår och höst på Capri, Italien. Interaktionen mellan bakvingens längd och säsongen var inte signifikant (p>0,05) i något av fallen och togs därför bort från den slutliga beräkningen.

Variable	S.S.	df	F	P
Abdomen				
Hindwing length^3	1393.3	1	12.61	0.001
Season	15.9	1	0.14	0.707
Error	4307.8	39		
Total	44327.1	41		
Thorax				
Hindwing length^3	2615.2	1	49.48	<0.001
Season	0.2	1	0.04	0.951
Error	2061.4	39		
Total	100509.2	41		

Discussion

There are at least three possible explanations to the difference in hindwing length found in spring and autumn: abrasion, differential mortality or the appearance of a different generation. First, only individuals with undamaged wings were included in the analysis, and therefore abrasion is a highly unlikely cause of the seasonal difference in hindwing length. Second, the difference in hindwing length could be caused by a higher mortality rate during winter for larger individuals. If this is the case the mean value of hindwing length would decrease but the range of lengths found would look similar between the two seasons. The hindwing length of many of the spring individuals was well below the smallest individuals found in autumn (Figure 1). Further, a study of monarchs showed that smaller individuals died in larger proportions during winter (AlonsoMejia et al. 1997). Third and last, the autumn migrants might produce a new generation during winter in areas near Capri, which is the most likely explanation for the difference found in hindwing length between the seasons. This is also supported by the fact that there was no difference in dry mass when size was taken in account. Studies on monarchs that hibernate without extra energy intake during the winter period show that they build up large lipid reserves before hibernation (Beall 1948, AlonsoMejia et al. 1997. To build up large lipid reserves would be maladaptive for a butterfly that is active during winter, since bird predators would catch them easier (Dudley et al. 2002).

Stefanescu (2001) found that Red Admirals start to lay eggs as soon as they arrive in north-eastern Spain in late autumn. The larvae develop throughout the winter, and a new generation of adults appears in early spring. Stefanescu noted that the Red Admirals had very worn wings in autumn, but in spring the wings of the observed individuals were fresh, also suggesting that a new generation had been produced. The result from my study on Capri, adding a new site with a spring generation, supports the suggestion by Stefanescu (2001) that migrant populations of the Red Admiral all over the Mediterranean area are not hibernating but instead breeding during the winter.

One large difference with my study compared to other studies of lipid accumulation is that the butterflies have been allowed to feed in captivity before their mass was recorded. The data might therefore not show natural variations of lipid content. But on the other hand if the butterflies have an optimum level of lipid reserves, results might have looked different using freshly caught individuals since they might not have gained the lipid reserves they were trying to accumulate.

All butterflies in my study were males. The explanation is probably that male Red Admirals are territorial and perform hilltopping behaviours (Brown & Alcock 1990). They often perch on

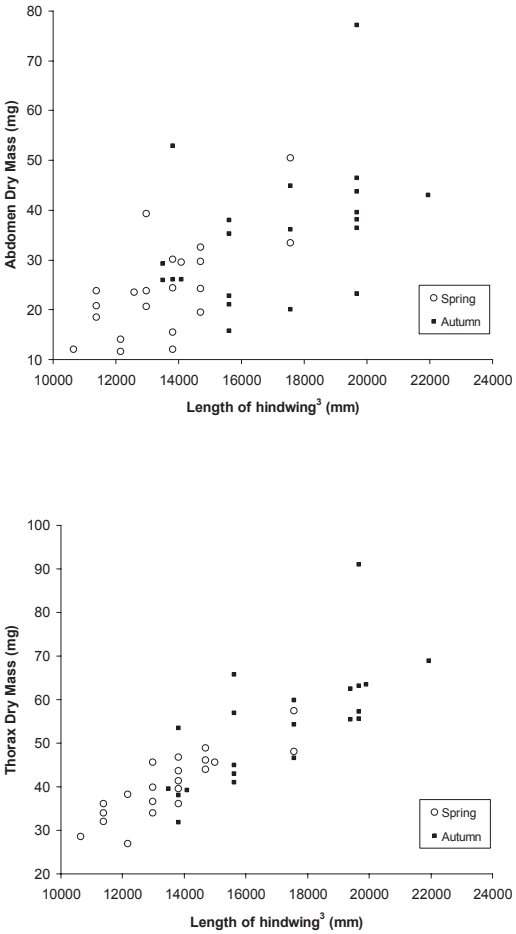

Figure 1. Relationship between hindwing length and dry mass of abdomen (a) and thorax (b) from male Red Admirals Vanessa atalanta caught during spring and autumn on Capri. To make all data points visible, a few of them have been slightly adjusted.
Förhållandet mellan bakvingens längd och torrvikten av abdomen (a) och thorax (b) hos hanar av amiral Vanessa atalanta fångade under vår och höst på Carpri. För att göra alla punkter synliga har ett fåtal flyttats något.

rocks, making them easy to spot in the field. In the future it would be most interesting to include females and analyse the relationship between dry mass and lipid content in detail.

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Sammanfattning

Många dagfjärilar flyttar i likhet med fåglar långa sträckor varje år. Hur fåglar lagrar upp fett inför flyttningen är välstuderat men hos fjärilar är det endast den amerikanska monarken *Danaus plexippus* som är relativt välstuderad. Monarker övervintrar i Mexico och flyttar norrut på våren genom större delen av Nordamerika för att senare återvända på hösten. Under den årliga flyttcykeln varierar mängden fett, precis som hos fåglar, kraftigt beroende på behovet av lagrad energi. I Europa flyttar flera fjärilar långa sträckor men det finns knappast några studier av årliga variationer i fettupplagring. Amiralen *Vanessa atalanta* klarar inte av vinterklimatet i norra Europa utan spenderar huvudsakligen vintern i norra Medelhavsområdet. Under våren sprider de sig norrut genom hela Europa och återvänder sedan söderut på hösten och de individer som observeras på Capri övervintrar troligen i närområdet. I samband med en orienteringsstudie av Amiraler togs vingmått på individer från både höst (1–10 oktober 2004) och vår (9–20 maj 2005), mellankroppen och bakkroppen sparades för kontroll av kön och torrvikt. Endast individer med oskadade vingar togs med i analysen. Studier gjorda på Monarker har visat att större delen av variation i vikt hos individer av samma storlek beror på skillnad i lagrat fett varför vikt kan fungera som ett fettmått. Fjärilarna i den här studien hade haft fri tillgång till fruktoslösning under tiden i fångenskap (runt 3 dagar) så vikten representerar inte exakt vad en ren fältstudie hade producerat utan snarare den mäng fett som fjärilarna strävar efter att uppnå. Totalt samlades 42 amiraler in, 21 på våren och 21 på hösten och alla visade sig vara hanar. Resultaten visade att amiralerna hade längre bakvingar på hösten men det fanns inte någon skillnad i torr vikt i förhållande till storlek (Figur 1). Störst variation fanns hos

bakkroppsvikten (Figur 1 b). Det finns tre möjliga förklaringar till skillnaden i vinglängd: slitage, högre vinterdödlighet för stora individer eller att individerna som fångas på våren tillhör en ny generation. Slitage är inte någon trolig förklaring eftersom endast individer med oskadade bakvingar är medtagna i analysen. Att större individer skulle ha högre dödlighet är inte heller troligt eftersom en stor del av de individer som fångats på våren är mindre än de minsta höstindividerna. Den troligaste förklaringen är att amiralerna förökar sig under vintern och att vårindividerna kommer från en helt ny generation. Detta stöds även av att det inte fanns några säsongsberoende skillnader i vikt. Om amiralerna är aktiva under vintersäsongen behöver de inte lagra upp fett, en stor fettdepå skulle göra dem långsammare och därmed ett lättare byte för predatorer. Slutsatsen är alltså att amiralerna i områdena runt Capri är aktiva och förökar sig under vintern. Individer från den nya generationen som flyttar norrut nästa vår är mindre än de som anlände norrifrån på hösten.